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IS 10106-1-4 (1995): Packaging code, Part 1: Product packaging,section 4 Package cushioning design [TED 24: Transport Packages]

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भारतीय मानक

पैकेजबंदी संहिता

भाग 1 उत्पाद पैकेज

भाग 4 पैकेज गद्देदार डिज़ाइन

Indian Standard

PACKAGING CODE

PART 1 PRODUCT PACKAGING

Section 4 Package Cushioning Design

UDC 621·798·22

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

March 1995

Price Group 7

FOREWORD

This Indian Standard (Part 1/Sec 4) was adopted by the Bureau of Indian Standards, after the draft finalized by the Packaging Codes Sectional Committee had been approved by the Light Mechanical Engineering Division Council

During transportation and handling a product is liable to damage from impact, shock or vibration as they are transmitted to the contents of the package. It is, therefore, desired to reduce the shock by giving protection to the product within the container, by the use of special material or device which will absorb whole or part of the impact shock or vibration. Cushioning is, therefore, that part of packaging which protects article from damage due to shock or vibration.

Various types of resilient materials are used for cushioning of engineering equipment, which vary in the way they deform and also in their ability to recover from such deformation. The commonly used materials include:

a) Non Crosslinked Polyethylene Foam;
b) Rubberised Coir;
c) Expanded Polystyrene Foam;
d) Polyurethane Foam;
e) Sealed Air Cushions;
f) Shock Mount; and
g) Springs.

This section of packaging code (Part 1/Sec 4) covers the guidelines for evolving package cushioning design on scientific basis for engineering equipment using two of the more commonly used cushioning materials, namely, non-cross link polyethylene foam and rubberised coir. The applicability of this document is, however, recommended for such equipment whose fragility can be represented in term of gravitational acceleration units.

Procedure for generation of the required data has also been included in Annex A.

Classification of equipments based on their fragility levels included in this standard is of a very general nature and the data can only be applied when no such information is available. In such cases it is recommended that the adequacy of the design evolved by adopting the fragility levels given, the equipment for satisfactory performance.

Packaging code is being published in several parts. Various parts cover the following aspects:

Part 1 Product Packaging Section
Part 2 Packaging Materials Section
Part 3 Ancillary Materials Section
Part 4 Packages Section
Part 5 Packaging Machinery

Indian Standard
PACKAGING CODE
PART 1 PRODUCT PACKAGING
Section 4 Package Cushioning Design

1 SCOPE

1.1 This standard (Part 1/Sec 4) provides recommendations and guidance on commonly used indigenous cushioning materials (non-cross link polyethylene foam and rubberised coir) along with the relevant data from which package cushion for delicate equipment may be designed for best protection during transportation and handling.

1.2 Similar data may be generated for other materials like polystyrene foam, polyurethane foam and other processed resilient materials. Annex A gives the procedure to be followed.

2 FUNCTION OF CUSHIONING MATERIALS

Cushioning materials find use in a variety of applications namely:

a) To protect the equipment from transportation shocks and vibration.

b) Immobilization – To hold the delicate equipment always in position firmly inside the package preventing relative movement.

c) To pad sharp corners to prevent tearing or puncturing of barrier materials.

d) As Dunnage – To fill voids inside package, created by concept of economical cushioning design.

e) As Separators – Between two surfaces to prevent rubbing and thereby reduce polishing, erosion of paints, etc.

3 SELECTION OF CUSHIONING MATERIALS

3.1 Not all cushioning materials available commercially lend themselves to scientific cushioning design. The following are the main considerations that merit selection of materials for evaluation of characteristics.

3.1.1 Material shall be a processed one so that quality in manufacture can be controlled and data generated on one batch of material can be applied to other batches in the production run.

3.1.2 Materials shall be available in several thickness and densities so that it can be used for varied cushioning requirements.

3.1.3 Material shall be produced to agreed tolerances.

Length, Width = ± 20 mm or ± 3%
Thickness = – 0, + 10%
Density = ± 10%

3.1.4 *Economic Viability*

It is always preferred to choose materials based on characteristics which are necessary and sufficient for the particular equipment and drop height requirements of that optimum cushioning design results.

4 PROPERTIES OF CUSHIONING MATERIALS

4.1 Cushioning Properties

4.1.1 *Resiliency*

It is the ability of cushioning material to undergo deformation on application of load and the ability to recover repeatedly and almost completely on removing the applied load. This poverty relates to shock absorption properties of the cushioning materials and therefore is of prime significance which is rated in terms of 'G' factor and is dependent on 'G' fragility factor of the equipment. This document provides a set of cushioning curves from which optimum cushioning, thickness, density, length and width of cushioning material can be arrived for protection against transportation shocks.

4.1.2 *Compression Set*

It is a permanent deformation of the material due to either static load on the system or repeated transit compression. In simple words, it can be defined as the difference between the original thickness of the cushioning material and thickness of the same after having been released from compression under standard load for the certain period of time and is expressed in percentage of the material thickness. Compression set will vary depending on load, temperature conditions, bearing area and thickness. If compression set is high, the cushioning ability and utility of the material in reuse will be sacrificed.

4.1.3 *Rate of Recovery*

This indicates time taken by cushioning material to return to its original shape. Faster recovery might damage the product due to spring back action. There are cushioning materials like expanded polystyrene where one may not find recovery at all. This too is not suitable for the many equipments.

4.1.4 *Peak G* vs *Static Stress*

This document provides a set of design curves for:

i) Non-cross link polyethylene foam (Fig. 1 to 14), and Annex B

ii) Rubberised Coir (Fig. 15 to 22)

from which optimum cushioning specification can be evolved, that is, density, thickness, length and width of the cushioning material can be arrived at for safe transportation and handling.

4.1.5 *Creep*

Creep is also known as cold flow which is common in all cushioning material. It is strain-time response of a cushioning material. It is strain-time response of a cushioning material to constant stress.

4.1.6 *Damping*

Damping is the periodic oscillation of the material before it comes to rest. When the resilient cushioning material is compressed with certain load and released after sometime, it should not come to rest with oscillation.

4.2 Non-Cushioning Properties

Non-cushioning properties are the properties which do not isolate equipment from shock and vibration but are very important in selection of cushioning material.

4.2.1 *Dusting*

The low structure strength of cushioning material causes disintegration under load which reduces the cushioning performance. Almost all cushioning materials except expanded polyethylene and air bubble film are prone to dusting.

4.2.2 *Abrasive Characteristics*

Smooth and precision surfaces like lenses or highly polished or painted surfaces need protection from abrasion from wrapping or cushioning material in contact.

4.2.3 *Chemical Resistance/Corrosion*

Product with critical surfaces need protection from corrosive effects. Cushioning material with high acidic or alkaline must be enclosed with waterproof or vapour barrier. The corrosive nature of cushioning material is indicated by *p*H of the material.

Similarly equipments with various acidic/alkaline surface should not react chemically with cushioning material. For this purpose also, cushion packaging should chemically inert.

4.2.4 *Hygroscopicity*

Cushion materials which absorb water under high humidity conditions are called hygroscopic and therefore the property is termed a hygroscopicity. It is an indication of uniform behaviour of cushioning material under various environmental change like summer, monsoon and winter. Hygroscopic cushioning materials have lower cushioning value, more compression set, higher creep, more corrosive effect, etc. When hygroscopic cushioning materials are used, some water proof barrier is required to avoid fall in performance of the product.

4.2.5 *Micro-Biological Effect*

Mould, mildew and some fungi normally develop over cushioning material surfaces under high humidity conditions or higher moisture content. Cushioning material should be free from such effect.

4.2.6 *Performance at Low Temperature*

During shipment at high altitude, cushioning material should behave 'Normal'. At lower temperature, almost all cushioning properties should be within performance limit to perform the basic function.

5 CUSHIONING DESIGN

5.1 The following information shall be made available for the application of this standard for designing a proper cushioning medium:

i) Status of the sample;
ii) Weight;
iii) Height of drop; and
iv) Fragility factor.

5.1.1 *Status of the Sample*

If the cushioning design based on this specification is to be more realistic and practical, a true representative equipment of bulk production shall be provided for cushioning design and evaluation.

5.1.2 *Weight*

The use of the peak G *versus* static stress curves given in Fig. 1 to 22 is based on fragility levels and the stress (Wt/area) of the equipment requiring packaging. Hence the stress on all faces shall be calculated and the maximum stress amongst these figures only is taken while referring to design curves.

5.1.3 *The Height of Drop*

The height from which an object drops determines the velocity of impact. It is therefore, an important factor in determining the cushioning required. Table 1 indicates likely drop height under various situations.

5.1.3.1 A more accurate method to choose the drop height is to make use of probability curves (*see* Fig. 23). They show the probability of a drop occurring from a specific height, or higher, in relation to the mass of the object, or, in other words, they indicate the probability of product damage.

By applying these curves, it will be possible to optimise the total costs of anticipated product damage and of packaging in relation to drop height as the basis of the packaging design (*see* Fig. 24).

5.1.3.2 Interpretation of the graph:

- the higher the chosen drop height, the lower the probability that an object will fall from that height and therefore the lower will be the probable damage costs.
- but the higher the chosen drop height, the more expensive will be the packaging costs to cushion an item properly for that drop height.
- the optimum is identified above as the minimum of the sum of the probable damage costs plus the total packaging costs.
- potential damage costs is the total cost when a product is damaged (product value, freight, insurance, related services, etc) times the probability that damage will occur.

Table 1 Drop Height Under Various Situations

(*Clause* 5.1.3)

Weight Range Gross Weight in kg	Type of Handling	Drop Height in mm
0-10	One man throwing	1050
11-25	One man carrying	900
26-125	Two men carrying	750
126-250	Light equipment handling	600
251-500	Light equipment handling	450
501 and above	Heavy equipment handling	300

- total packaging-related cost includes cost of cushion material, outerpack, assembly, storage and average transportation cost of final goods. This means that there is a drop height at which the total costs will be at a minimum. It implies that certain product damage has to be tolerated when costs are optimised.

Hence, final acceptance of the cushioning design shall be subject to the following:

a) Rig up the package using a working model of the equipment.
b) Conduct drop tests on all the six faces from drop height as specified in Table 1.
c) If the equipment fails indicating inadequacy of cushioning medium which again indicates the error in adopting a particular fragility level from Table 2, redesign the cushioning presuming a lower fragility level.

5.1.4 *Fragility Factor (FF)*

This is defined as the maximum mechanical shock the equipment is capable of withstanding without failure. It is likely that this characteristic vary from direction to direction of shock application. Hence, when the equipment is evaluated, the least of the values of shock that causes failure amongst all the three directions of application shall be taken as fragility factor. Since, this value of fragility factor generated by evaluation of one equipment is required to be applied for bulk production a safety factor of 0.8 times the test figure is taken for cushioning calculation. The values indicated on Y-axis of the curves shown in Fig. 1 to 22 correspond to shock sensed by transducer when a particular stress falls on to a particular cushioning material from the indicated height. This shock should be less than or equal to fragility factor of the cargo. Where facilities for evaluating fragility factor do not exist, reference may be made to Table 2 in which different types of engineering equipments have been categorised and recommended fragility factor assigned.

Table 2 Approximate Fragility of Typical Packaged Articles

(*Clause* 5.1.4)

Degree of Fragility	Type of Equipment	Fragility Factor, G
Extremely fragile	Missile guidance system	15-25
Very delicate	Mechanically shock mounted instruments and electronic equipment	25-40
Delicate	Aircraft accessories, electric typewriters, cash registers and office equipment	40-60
Moderately delicate	TV receiver, air-craft accessories	60-85
Moderately rugged	Major appliances	85-115
Ragged	Machinery	115 and above

NOTE – Above specifications of G values are estimated ones and for exact range of G values of specific components/articles/objects, individual testing shall be required.

6 EXAMPLE

6.1 The example given below illustrates the application of data given in this standard for cushioning design:

"A professional grade rectangular cubicle electronic equipment weighing 18 kg with overall dimensions of 0.6 m X 0.38 m X 0.25 m is required to be cushioned against transportational hazards for drop height of 60 cm."

Step 1 – Calculation of stress

$$\text{Face } 1 = \frac{18}{60 \times 25} = 0.012 \text{ kg/cm}^2$$

$$\text{Face } 2 = \frac{18}{60 \times 38} = 0.007\,9 \text{ kg/cm}^2$$

$$\text{Face } 3 = \frac{18}{38 \times 25} = 0.189 \text{ kg/cm}^2$$

Choose the maximum stress, that is, 0.018 9 kg/cm^2 for cushioning design.

Step 2 – Find out the ratio height corresponding to equipment weight of 18 kg from Table 1. Specified height of drop is 60 cm.

Step 3 – Determine fragility factor of equipment using any standard test facility and instrumentation. Report the test on all the three faces, and take least of the three values. For application to bulk production lot, 0.8 times of this figure is to be taken for cushioning design calculation.

In case facility for fragility factor assessment does not exist with package designing agnecy, Table 2 may be consulted. For a professional grade electronic equipment, Table 2 gives FF of 60 and therefore, 60 x 0.8 = 48 should be considered for actual calculation.

Step 4 – Refer to the curves (Fig. 1 to 14) and choose proper material. The choice is between rubberised coir and foamed polyethylene. Fig. 1 to 14 relate to peak *G versus* static stress data for foamed cross link polyethylene and Fig. 15 to 22 for rubberised coir.

Fragility factor that is, 48 is to be located on Y-axis and see if any of the curves for 60 cm drop falls below this level.

From the curves it may be seen that 100 mm thick foamed polyethylene. If the choice is open between the two mateirals depending on the stress level and the fragility factor, the one which is found to be more economical can be adopted.

ANNEX A

(*Clause* 1.2)

PROCEDURE FOR EVOLVING CHARACTERISTIC DESIGN CURVES FOR CUSHIONING MATERIALS

A-1 FACILITY REQUIRED

The machine used to generate this data is called "Dynamic Cushioning Tester".

The machine has a high impact polystyrene carriage moving on wheels over four vertical uprights. The machined smooth uprights are hard chromium plated to provide a wear resistant surface. The carriage can be taken up and released from a desired height by means of an electromagnet. Facility exists to add weights to the carriage to increase the stress on the cushioning material on which it drops.

A-1.1 Friction Correction

Although the carriage executes almost frictionless motion on the vertical uprights, it can be considered to be a "freedrop". Small correction is applied to the height of drop of the carriage as it is dropped on the uprights to get equivalent free drop height as follows:

$$H = \frac{1}{2}(a \times t \times t_1)$$

where

H = equivalent free full height to a preset drop height of 'h' on the machine. $H > h$ for frictional drop;

a = g;

t = freefall time; and

t_1 = measured time of drop. $t_1 > t$.

A-1.2 Specimen Selection

The following care shall be exercised while choosing cushioning material for this evaluation:

1) Material shall be a processed one so that the quality can be maintained and the data generated on one batch can be applied to subsequent batches.
2) The material shall be available in more than one density and thickness.
3) The manufacturer shall be able to maintain agreed tolerances on dimensions and density.

NOTE – The manufacturer who wishes to obtain his material classified to this specimen shall agree to let know the testing authority the changes he may bring about in the material composition and processes in course of time and submit samples for reclassification.

A-2 TEST PROCEDURE

A-2.1 Instrumentation

A-2.1.1 Suitable instrumentation consists of an accelerometer system meeting with the following general requirements:

a) Dynamic amplitude range : 5 – 200 g
b) Frequency response :
  Low frequency limit : Down to DC
  High frequency limit : 2 000 Hz
  Mid band : Flat within 1 db
c) Phase shift : Should be either zero or there should be a constant time delay to all frequencies up to 1 700 Hz.
d) Linearity : Amplitude sensitivity of the system should be linear within 1% over the rated amplitude range.
e) Accuracy : Better than 10%
f) Temperature range : 15° – 25°C
g) Resolution : The system shall have a resolution and repeatability better than 1 g or 3% whichever is the greater.

A-2.1.2 Requirements for the individual units in the accelerometer system:

a) *Transducer* : The mounted resonant frequency of the transducer should be not less than:
  i) 10 KHz where there is negligible damping.
  ii) 3 KHz where the transducer is velocity damped.
  iii) Negligible mass compared to the mass of the moving system.
  iv) Transverse sensitivity shall be less than 5% of the principal – axis sensitivity.
b) *Connecting leads* : Low-noice co-axial cable.
c) *Power supply to transducer* : Where an alternating carrier voltage is applied to the transducer, the frequency of the supply < KHz.

A-3 Calibration

A-3.1 Calibrate the carriage for loss of height due to friction using the equivalent $H = \frac{1}{2}(a \times t \times t_1)$

A-3.2 Carry out the following test for different drop heights for various thicknesses and densities of cushioning materials.

"Place the cushioning materials (size in plan 30 cm x 30 cm) on the drop platform and allow the carriage to drop on to the cushioning materials. Record the shock. For the same drop height, increase the weight of the carriage and repeat the drop to get shock levels for different stresses and plot.

Repeat each drop for at least four times and take mean of the four readings.

ANNEX B

[*Clause* 4.1.4 (i)]

TECHNICAL PROPERTIES OF NON CROSSLINKED POLYETHYLENE FOAM

Density	25 to 40 kg/m^3
Tensile strength	0.2 N/mm^2
Elongation at break	105%
Tear resistance	1.95 N/mm
Compresive stress 4th compression	
– at 25% deformation	0.035 N/mm^2
– at 50% deformation	0.105 N/mm^2
Compression set 22h/23°C/50% after 24h	11%
Thermal stability	< 3%
Compressive creep 0.07 kg/cm^2 1 000 h at 23°C	< 5%
Cell size Cells/25 mm	13 to 25

Dynamic Cushioning Curves

Drop Height	*Foam Thickness*
150 mm	50 mm
300 mm	50 and 70 mm
450 mm	50 mm
600 mm	50, 70, 80 and 100 mm
750 mm	50, 70, 80 and 100 mm
900 mm	100 mm
1 350 mm	70, 80 and 100 mm

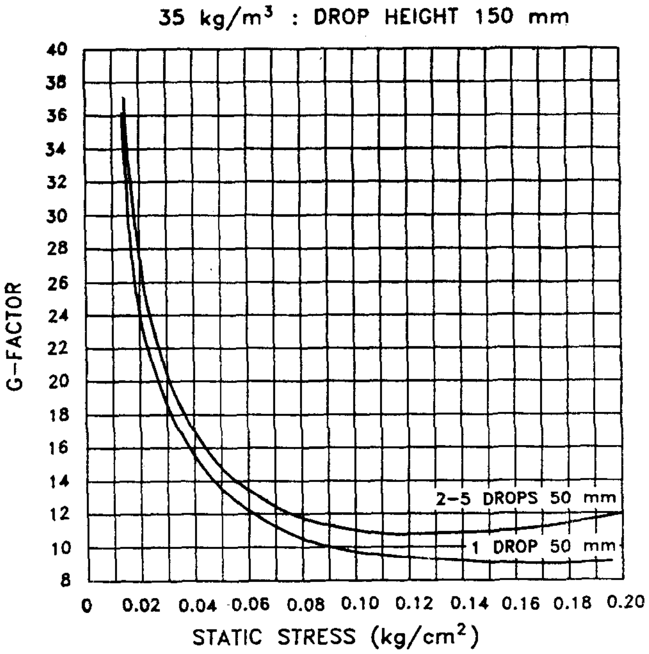
35 kg/m³ : DROP HEIGHT 150 mm

FIG. 1 DYNAMIC CUSHIONING CURVES

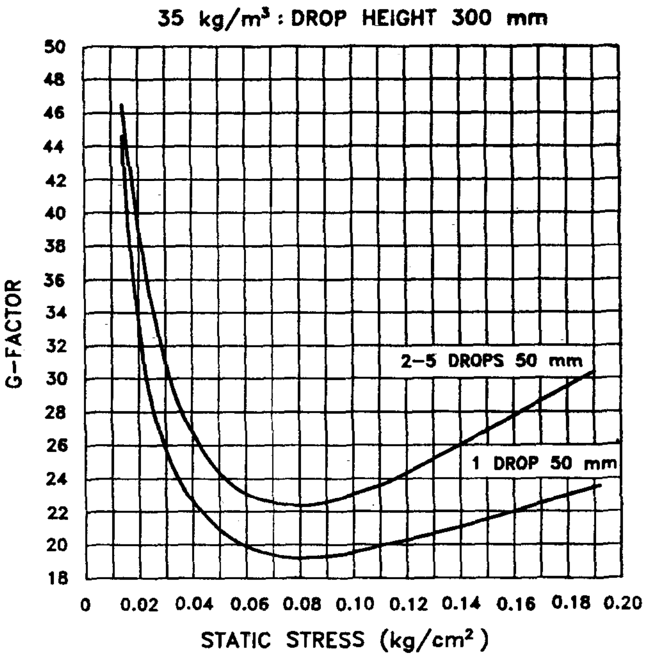
35 kg/m³ : DROP HEIGHT 300 mm

FIG. 2 DYNAMIC CUSHIONING CURVES

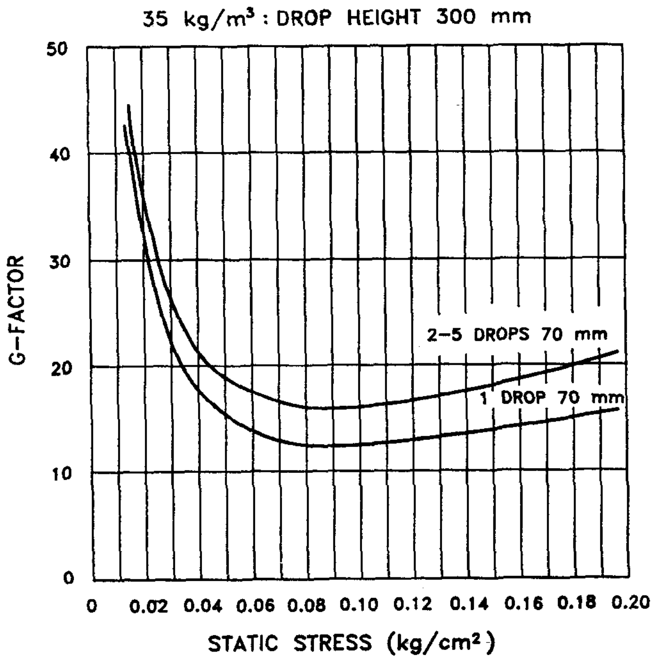
35 kg/m³ : DROP HEIGHT 300 mm

FIG. 3 DYNAMIC CUSHIONING CURVES

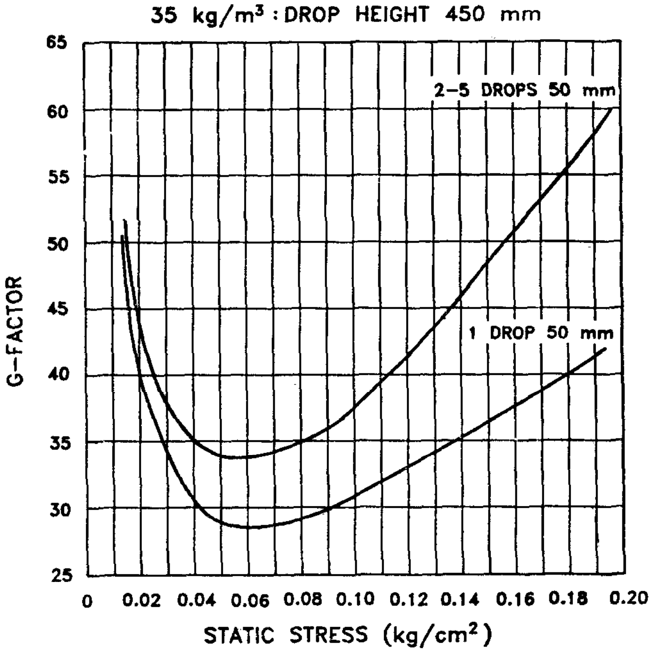
35 kg/m³ : DROP HEIGHT 450 mm

FIG. 4 DYNAMIC CUSHIONING CURVES

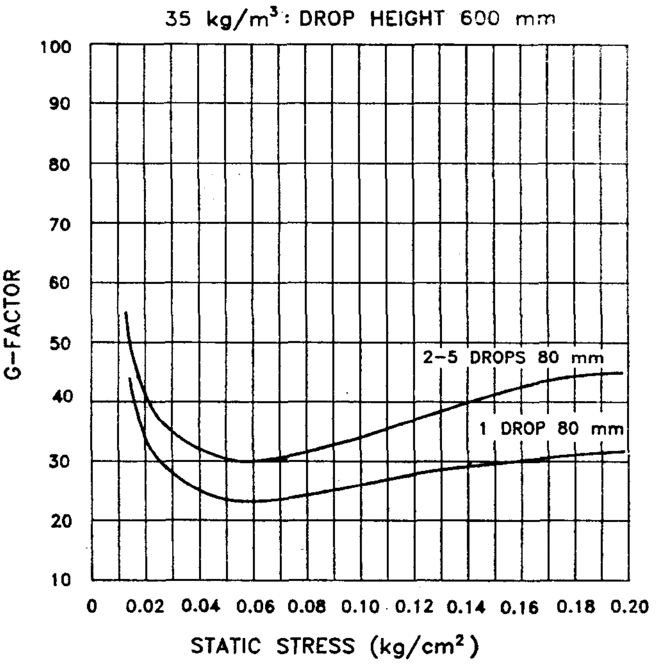

FIG. 5 DYNAMIC CUSHIONING CURVES

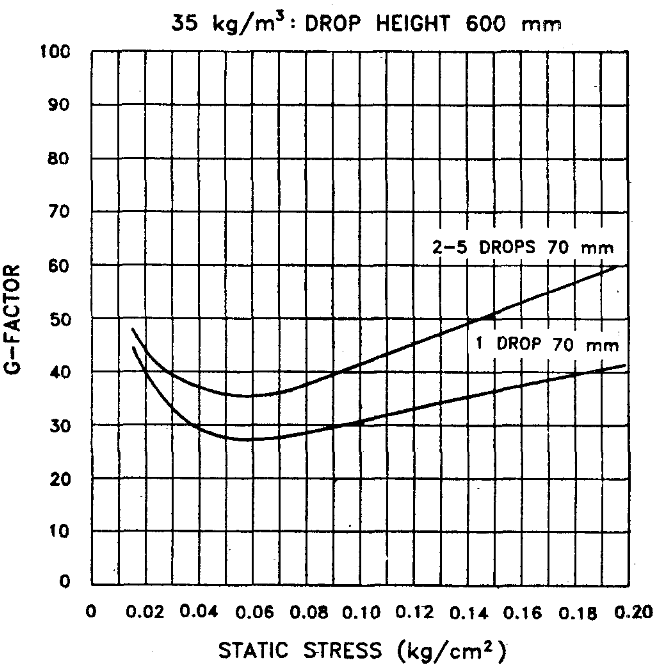

FIG. 6 DYNAMIC CUSHIONING CURVES

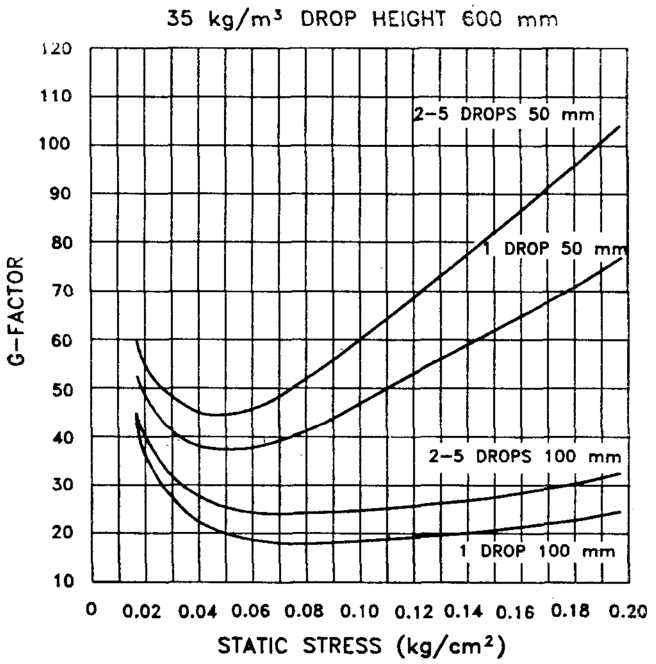

FIG. 7 DYNAMIC CUSHIONING CURVES

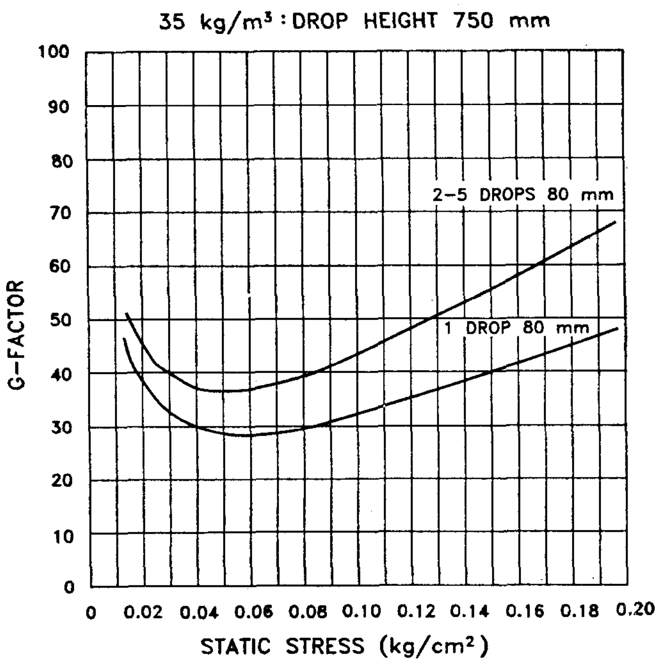

FIG. 8 DYNAMIC CUSHIONING CURVES

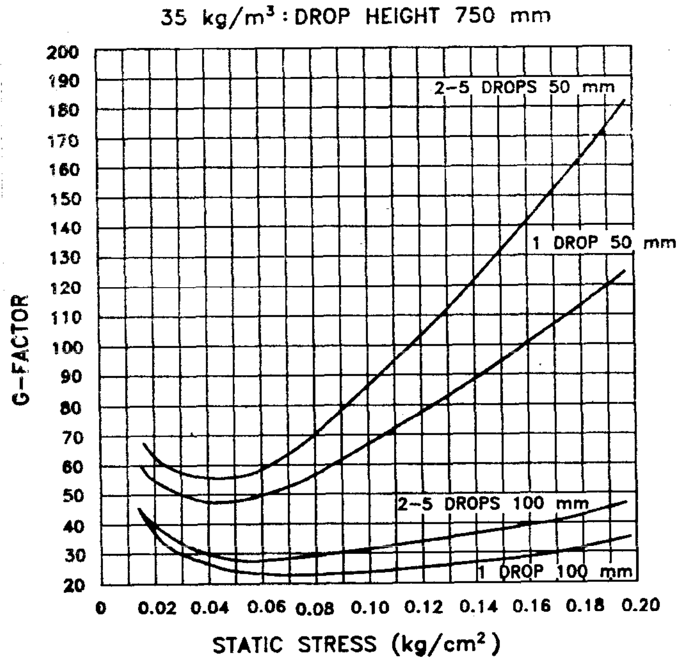

Fig. 9 Dynamic Cushioning Curves

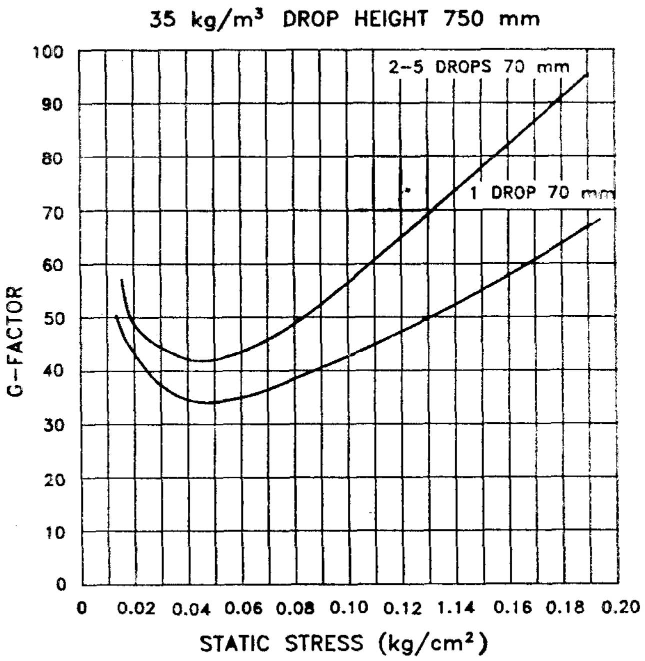

Fig. 10 Dynamic Cushioning Curves

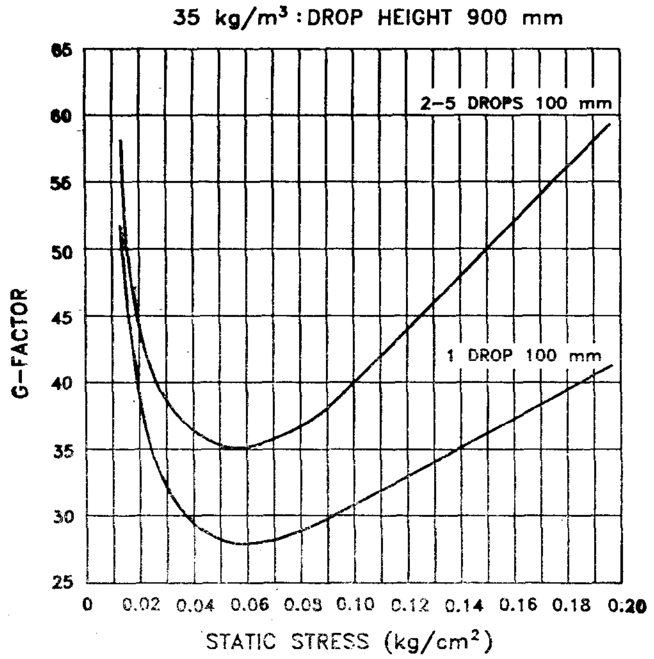

Fig. 11 Dynamic Cushioning Curves

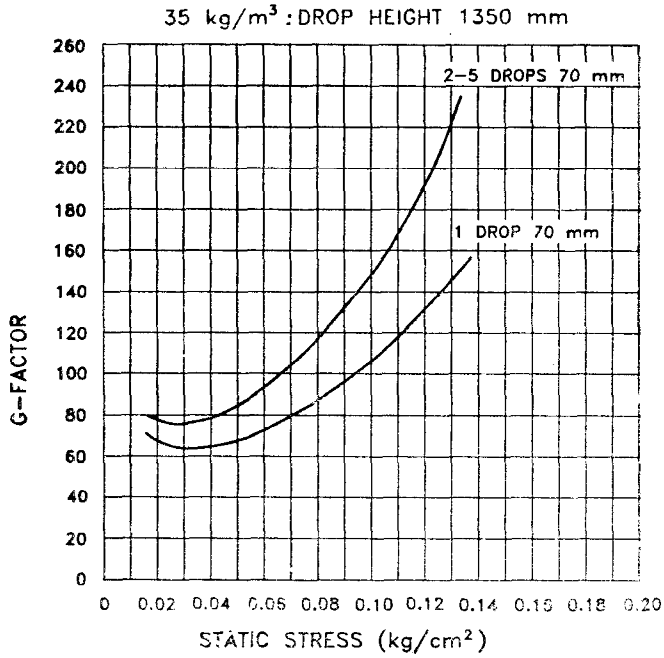

Fig. 12 Dynamic Cushioning Curves

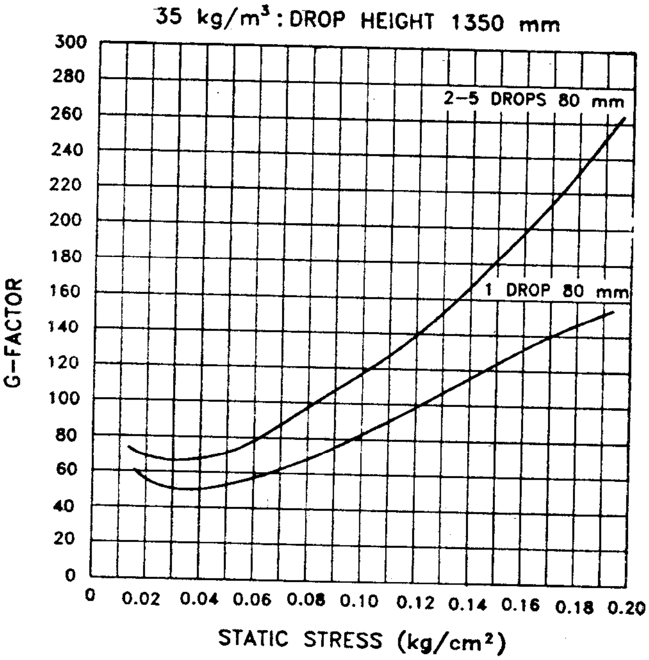

FIG. 13 DYNAMIC CUSHIONING CURVES

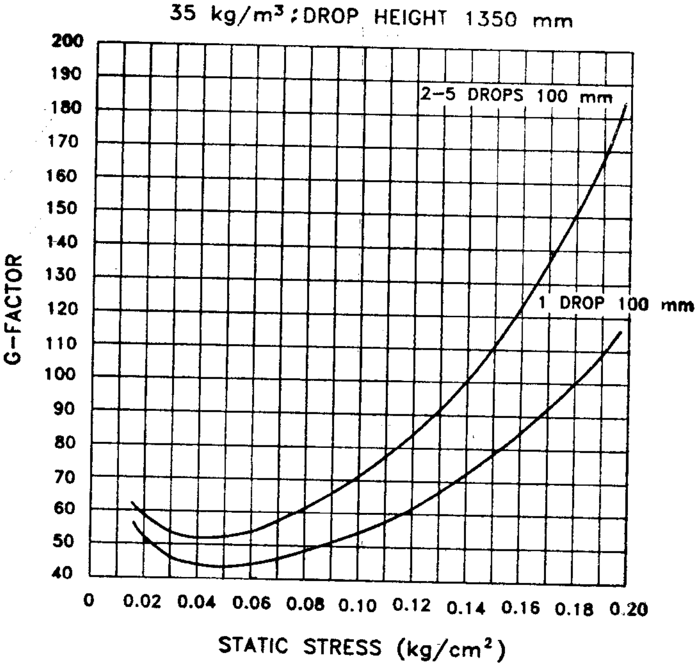

FIG. 14 DYNAMIC CUSHIONING CURVES

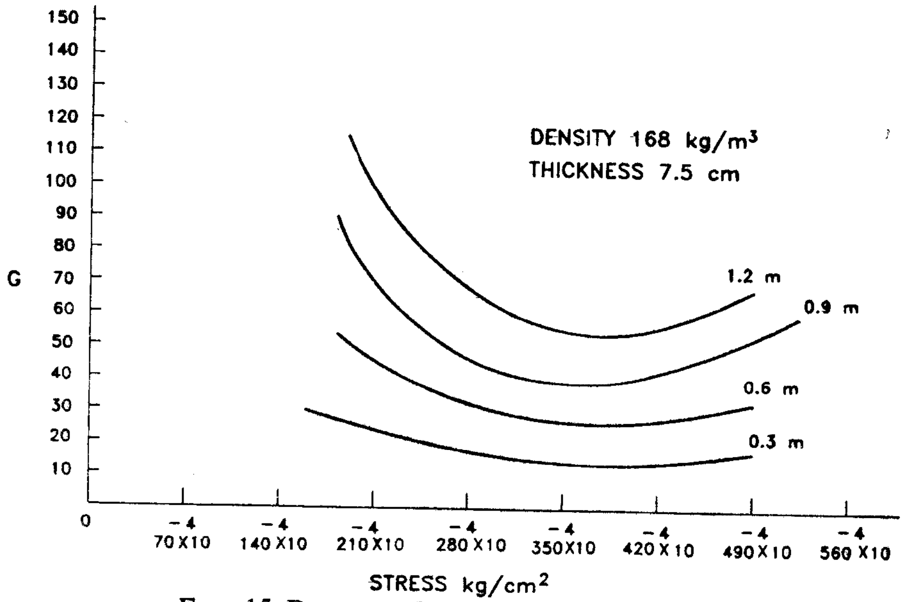

FIG. 15 DYNAMIC CUSHIONING CURVES

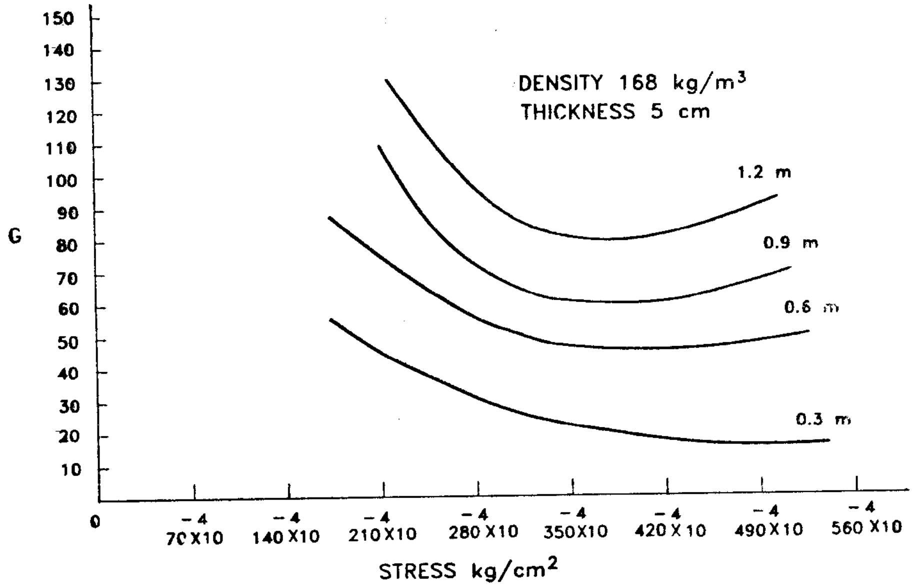

FIG. 16 DYNAMIC CUSHIONING CURVES

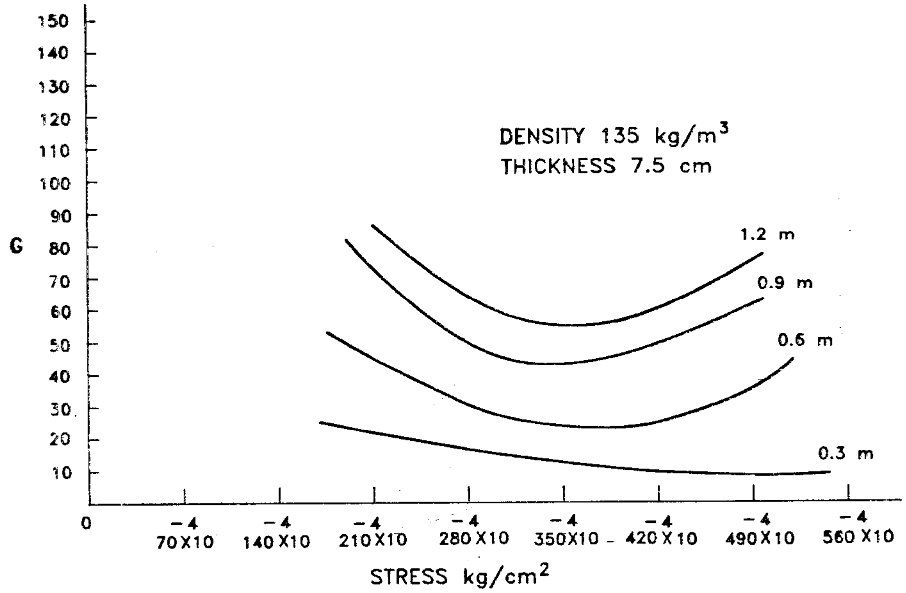

FIG. 17 DYNAMIC CUSHIONING CURVES

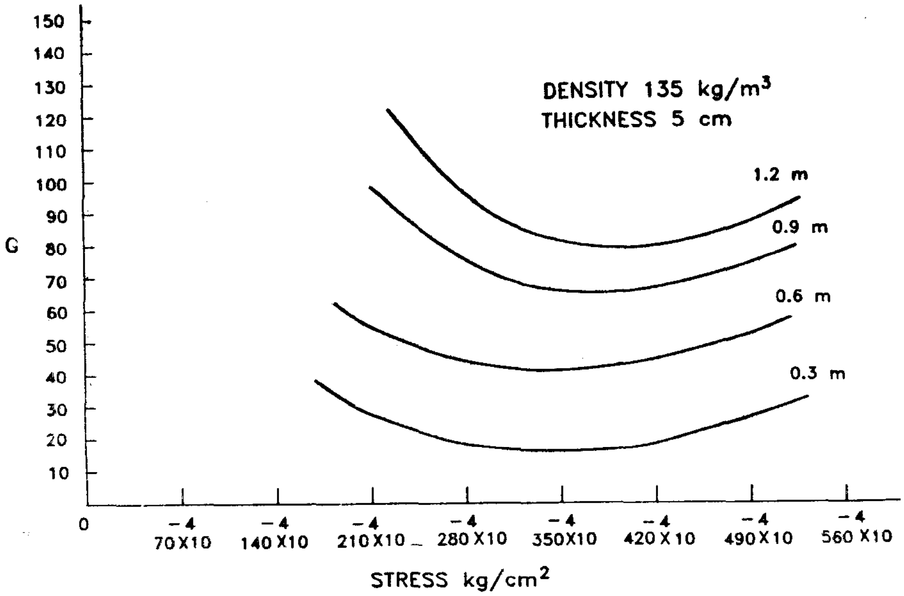

FIG. 18 DYNAMIC CUSHIONING CURVES

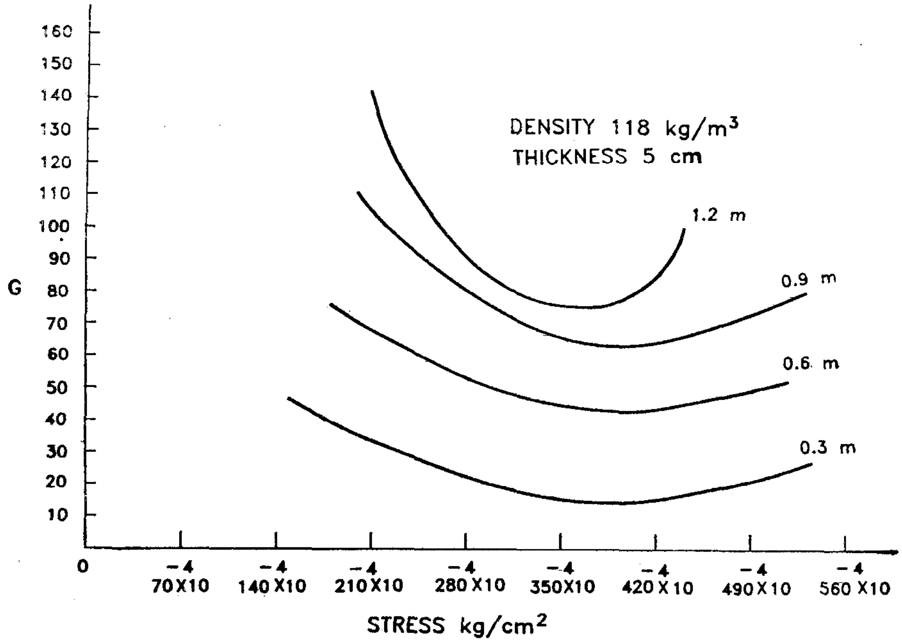

FIG. 19 DYNAMIC CUSHIONING CURVES

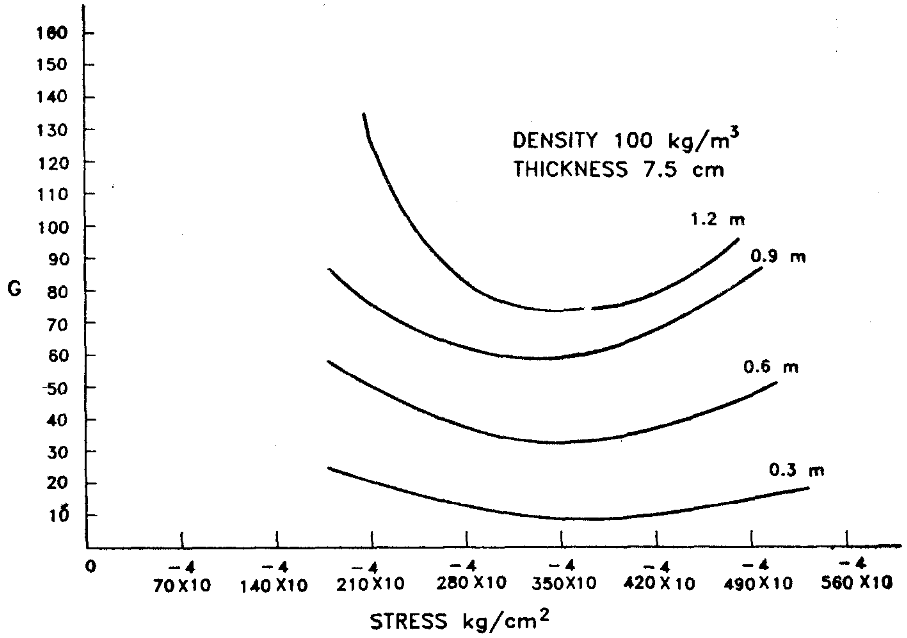

FIG. 20 DYNAMIC CUSHIONING CURVES

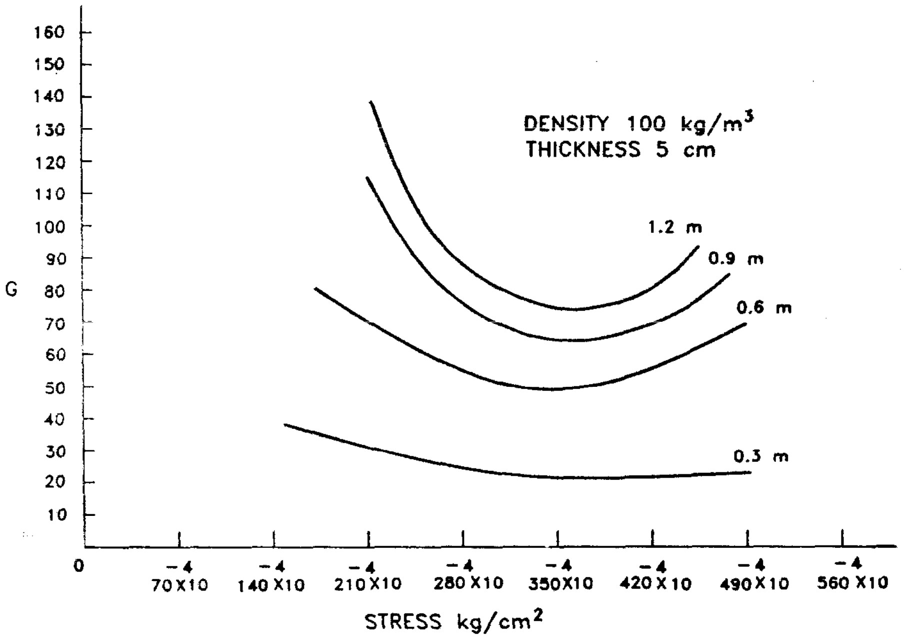

FIG. 21 DYNAMIC CUSHIONING CURVES

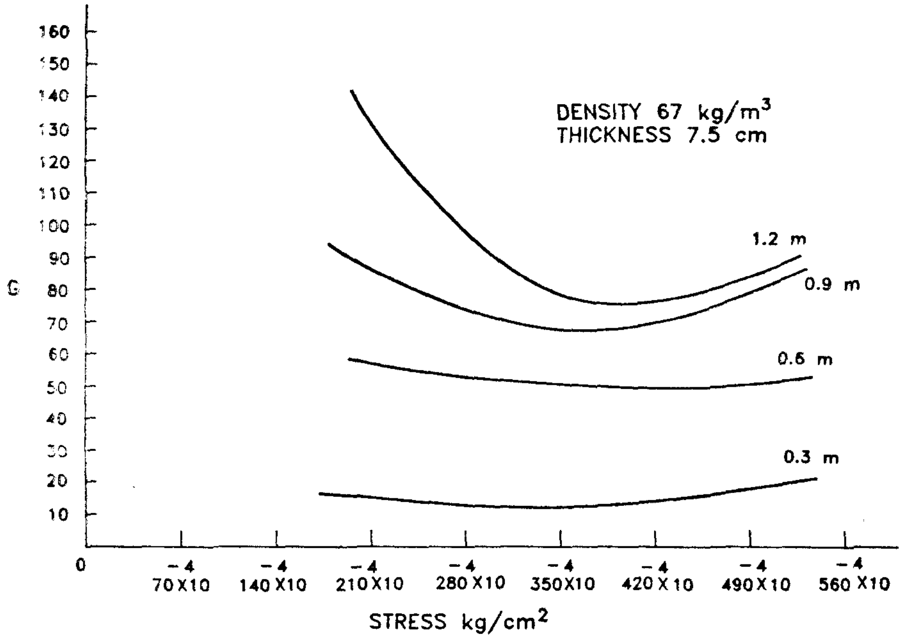

FIG. 22 DYNAMIC CUSHIONING CURVES

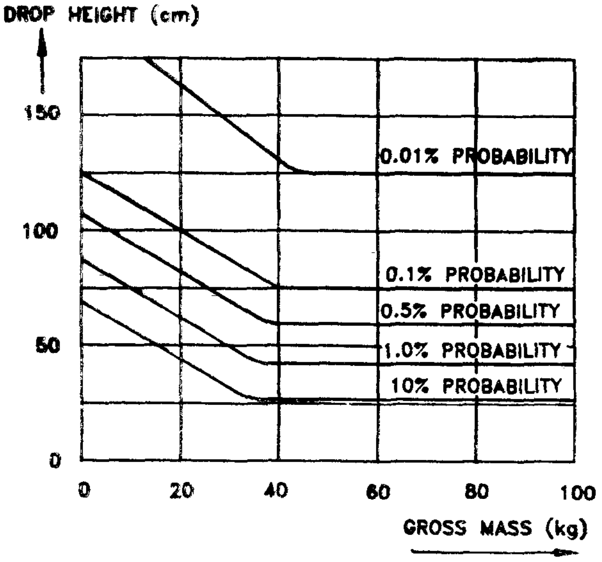

FIG. 23 PROBABILITY CURVES FOR HANDLING SHOCKS

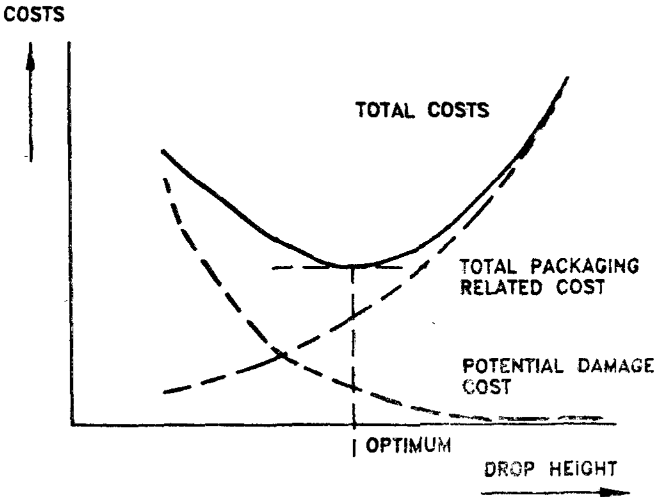

FIG. 24 OPTIMIZATION OF DROP HEIGHT[1] *VERSUS* COSTS BASED ON PROBABILITY CURVES

[1] To be used as basis for cushion packaging calculation.

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